Update to the WFPC2 Instrument Handbook

In This Document...

The Wide Field Planetary Camera 2 (WFPC2) is now a mature and largely well-characterized instrument. Information already available through the *WFPC2 Instrument Handbook* and the *HST Data Handbook* is fairly complete. In this update we provide additional information obtained from recent studies of the instrument, as well as calibration plans for the WFPC2 and a short note on present and planned imaging capabilities for HST. The major topics discussed in this document are:

- ***Charge Transfer Efficiency:*** Recent tests of the Charge Transfer Efficiency (CTE) of the WFPC2 charge-coupled diodes (CCDs) have shown that the fraction of charge "lost" to impurities in the CCD has grown with time. The CTE loss is particularly great in images with low backgrounds, and can, in some cases, significantly affect photometry. Users who plan to observe in modes that typically produce images with low backgrounds—for instance UV images, narrow-band images, and short exposures—should examine the section on CTE to see how this may affect their program.

- ***Point-Spread Functions:*** Progress has been made in recent years on the accurate subtraction of WFPC2 point-spread functions (PSFs) both to detect nearby faint companions of bright stellar objects and to obtain accurate stellar photometry. This document provides a short update describing the imaging dynamic range one can now expect to obtain near a bright stellar source, and our present understanding of the photometric accuracy one can obtain by PSF subtraction.
- ***Dithering:*** Dithering the telescope as a means of improving image resolution and removing detector defects has become increasingly popular among users of WFPC2 since the technique was successfully employed for the Hubble Deep Field. In this Update, we discuss the use of singly dithered observations (one image at each dither position). Software that we have recently developed can support such observations. The advantage of singly dithered observations is that more dither positions can be obtained in a given amount of time or number of exposures. The disadvantages are that the data is often far more difficult to reduce, and stellar photometry to better than a few percent cannot be guaranteed except in cases of excellent dithering coverage.
- ***Other Instruments:*** In addition to WFPC2, HST has two other imaging instruments, STIS and FOC, and in early 2000 the FOC will be replaced by the Advanced Camera for Surveys (ACS). A reminder of this fact, and its implications for planning observations, is provided.
- ***WFPC2 Clearinghouse:*** The WFPC2 group has developed a web-based tool, the WFPC2 Clearinghouse, to allow users to easily search journal articles, STScI documentation, and user-submitted documents for topics relating to the performance, calibration, and scientific use of WFPC2. This tool is described in the hope that the information made available by its use will help observers in the preparation of their observing plans, as well as in the reduction of their data.
- ***Calibration:*** Calibration of WFPC2 continues. We provide an updated table of system efficiencies and zeropoints, which differs slightly from that in the Instrument Handbook for certain narrow-band and UV filters. We also describe the plans for future calibration of WFPC2. Users who suspect that they will have unusual or particular calibration needs should examine the calibration plan to determine if they will need to take their own calibration observations as part of their HST observing program.

1.0 Charge Transfer Efficiency

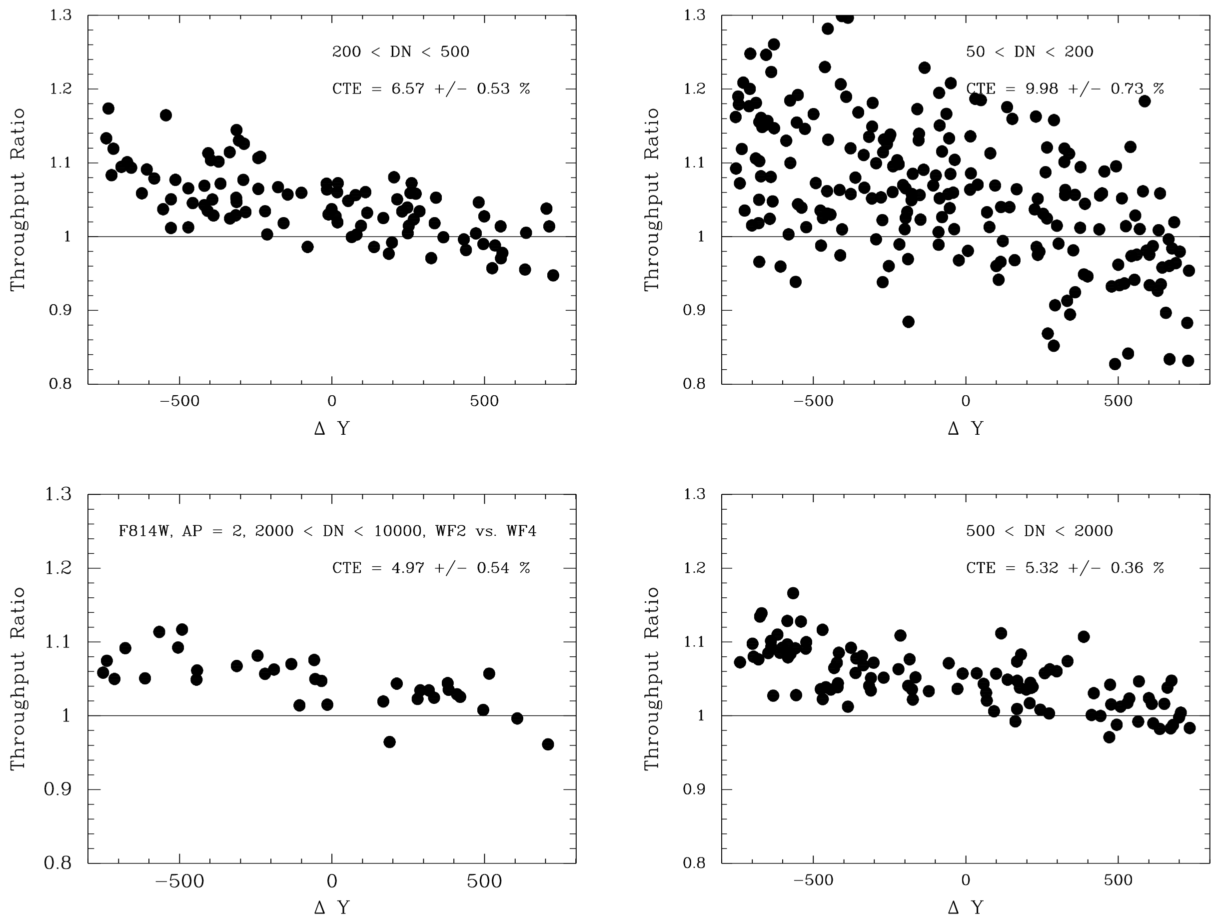
To be read in conjunction with Section 4.11 of the *WFPC2 Instrument Handbook*, Version 4.0.

During the past year, two studies were completed resulting in a better characterization of the Charge Transfer Efficiency (CTE) problem for WFPC2, based on an analysis of observations of the globular cluster Omega Cen (NGC 5139). The first study provides a set of formulae that can be used to correct for CTE loss when doing aperture photometry, based on a dataset taken on June 29, 1996 (WFPC2 ISR 97-08, Whitmore and Heyer, 1997).[1] The second study found evidence that CTE loss for faint stars has increased with time (Whitmore, 1998).

The primary observational consequence of CTE loss is that a point source at the top of the chip appears to be fainter than if observed at the bottom of the chip, due to the loss of electrons as the star is read out down the chip (see Figure 1). This is called *Y-CTE*. There also appears to be a similar, but weaker tendency, for stars on the right side of the chip to be fainter (called *X-CTE*). The effects also depend on the brightness of the star and the background level. Formulae are presented in WFPC2 ISR 97-08 that reduce the observational scatter in this particular dataset from 4–7% to 2–3%, depending on the filter.

1. A list of references is presented on page 26.

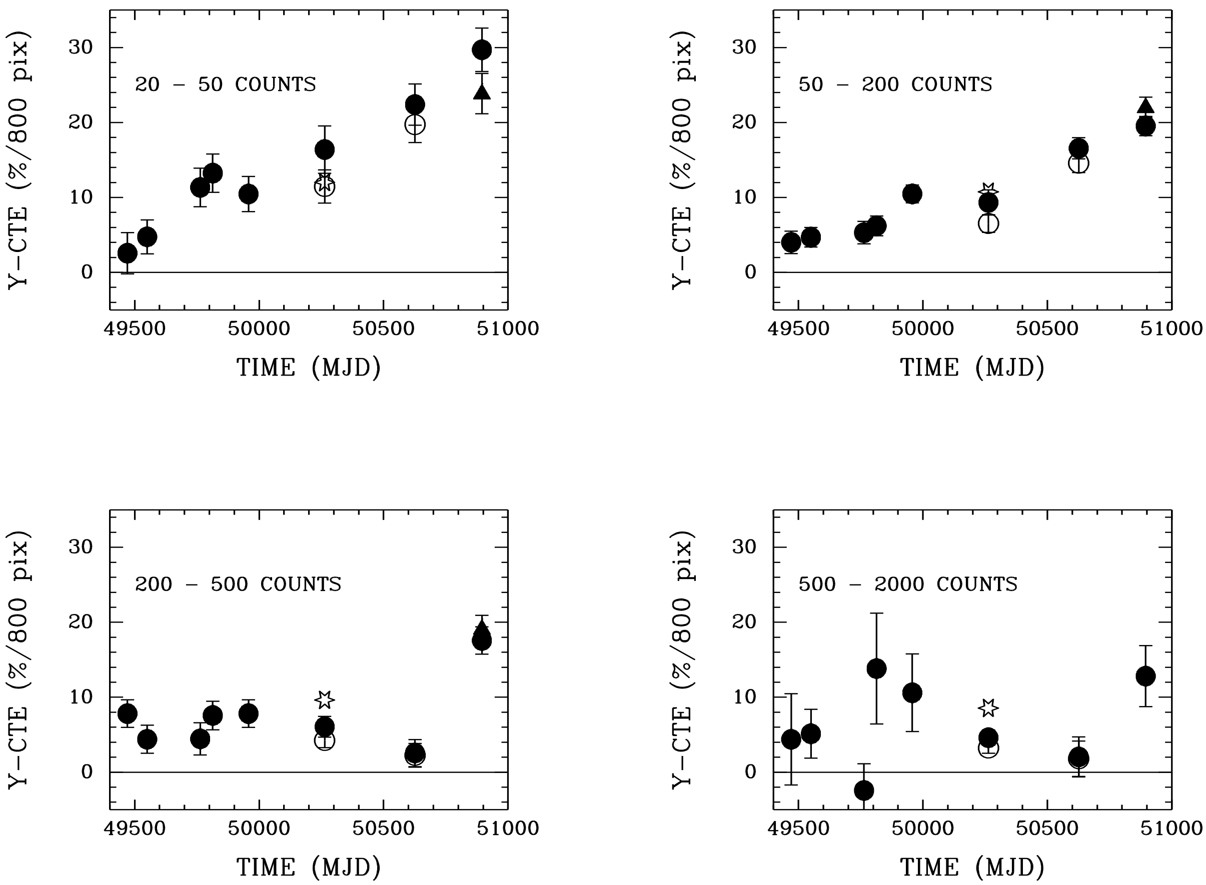
Figure 1: Ratio of count rates observed for the same star (i.e., throughput ratio) as a function of the change in Y position for stars in 4 different brightness ranges. The non-zero slope shows that a star appears brighter when it is at the top of the chip than when it is at the bottom of the chip. The effect is larger for fainter stars. See ISR 97-08 for details.



A continuation of this project based on a set of 8 observations of ω Cen suggests that CTE loss for WFPC2 is time dependent. The datasets cover the time range from April 28, 1994 (shortly after the cooldown) to March 23, 1998. For bright stars (i.e., brighter than 200 DN when using gain = 15; equivalent to 400 DN for gain = 7) there is only a modest increase in the amount of CTE loss as a function of time. However, for faint stars CTE loss has increased more rapidly. For example, for very faint stars (i.e., 20–50 DN at a gain of 15) the CTE loss has increased from 3% to 26% for a star at the top of the chip. There is no obvious change in the value of X-CTE.

It should be noted that these results are based on very short (14 second) exposures. In general, typical WFPC2 exposures are much longer than these short calibration images, resulting in higher background levels which significantly reduces the CTE loss and minimizes the CTE problem for most science observations. The observations used in Figure 2 below had backgrounds of ~0.1 DN/pixel.

Figure 2: Y-CTE loss as a function of time for four different ranges of the target brightness. The open circles represent measurements with exposure times longer than most of the other exposures (i.e., 14 seconds), with the normalized value shown above as a filled circle. The stars show the predictions based on the formulae in ISR 97-08 for the June 1996 data.



As an observer, there are a few different strategies for minimizing the effect of CTE loss. The first is to take longer exposures when possible, so the background is higher and the target brighter, both of which reduce CTE loss. Users thinking of dithering may wish to take this into account if they are considering shortened exposures to allow for more dither positions. When the highest possible accuracy is required another strategy would be to include a special calibration observation of ω Cen in your own program taken as close in time as possible to your own program target. Another strategy when only a single small target is required would be to place the target near the bottom of the CCD, though not too close so that edge effects become important. A further possible strategy is to preflash the chip to raise the background. However, tests indicate that the required level of preflash is so high that in general more is lost than gained by this method. A variation of this currently being tested is "noiseless" preflash, where a flatfield exposure is read out immediately prior to a short science exposure.[2]

Calibration proposal 7929 has been added to the Cycle 7 calibration plan in order to monitor CTE every 6 months.

2.0 The WFPC2 PSF: Dynamic Range and Photometry

To be read in conjunction with Chapter 5 of the *WFPC2 Instrument Handbook,* Version 4.0.

Here we supplement the Instrument Handbook with short discussions of the use of PSF subtraction to maximize image dynamic range and to obtain accurate stellar photometry. We also discuss a source of error in the published values of the HST aperture correction.

Dynamic Range

The WFPC2 PSF has structure on very small scales, with significant power on scales smaller than 1 PC pixel. Thus faint objects near bright objects can be difficult to detect and to distinguish from PSF artifacts. Model PSFs (for example those produced by the TinyTim software[3]) are quite good for many purposes, but can leave residuals as large as 10 to 20% of the peak.

Recent results indicate that PSF subtraction and detection of faint objects very close to bright objects can be improved by using a composite PSF from real data, especially dithered data. Table 1 indicates limits that may be obtained for well-exposed sources (nominal S/N > 10 for the faint object) where a dithered PSF image has been obtained.

2. More details can be found in Whitmore, 1998.

3. `http://scivax.stsci.edu/~krist/tinytim.html`

Table 1: Limiting Magnitudes for PSF Subtraction Near Bright Objects

Separation in arcsec (on PC)	Limiting Δm (without PSF subtraction)	Limiting Δm (with PSF subtraction)
0.15	2.5	5.0
0.25	4.5	6.4
0.4	6.5	7.3
1.0	8.9	10.7
3.0	10.7	12.9

A technique that has been used with some success to search for nearby neighbors of bright stars is to image a source at two different roll angles, and use one observation as the model PSF for the other. In the difference image the secondary source will appear as a positive residual at one position and a negative residual at a position separated by the change in roll angles. PSF artifacts generally do not depend on roll angle, but rather are fixed with respect to the telescope. Thus small changes in the PSF between observations will not display the positive or negative signature of a true astrophysical object. Again, it is recommended that the observations at each roll angle be dithered.

Photometry

PSF subtraction is also an effective means of accurate and repeatable photometry on HST. Papers presented at the 1997 HST Calibration Workshop by Remy et al. and Surdej et al. show that the subtraction of synthetic or scaled observed PSFs can be used to obtain 1–2% stellar photometry.

In spite of the ability to obtain photometry through PSF subtraction, the total fraction of the light of the PSF within a given radius is not known to better than a few percent due to the difficulty of measuring the light in the faint wings of stellar PSFs (remember that there are over 17,000 PC pixels inside a radius of 3″, each contributing read noise to the observation!). This difficulty has contributed to a minor error in Table 6.7 of the *WFPC2 Instrument Handbook*, which gives the fraction of encircled energy in the F555W filter within a 1″ radius as 100%. This table is based upon the encircled energy figures from Table 2(a) of Holtzman et al. (*PASP*, vol. 107, p.156, 1995). Examination of several filters shows that about 10% of the light in the PSF is missing at 1″ in the PC. Observers estimating aperture corrections for their images should be wary of this effect and note that in a later paper (Holtzman et al., *PASP*, vol. 107, p.1065, 1995) the same group normalized the HST magnitude system to the light enclosed inside of a 0.″5 radius to minimize errors caused by the uncertain aperture correction at large radii.

3.0 Dithering with WFPC2

To be read in conjunction with Section 7.6 of the *WFPC2 Instrument Handbook*, Version 4.0

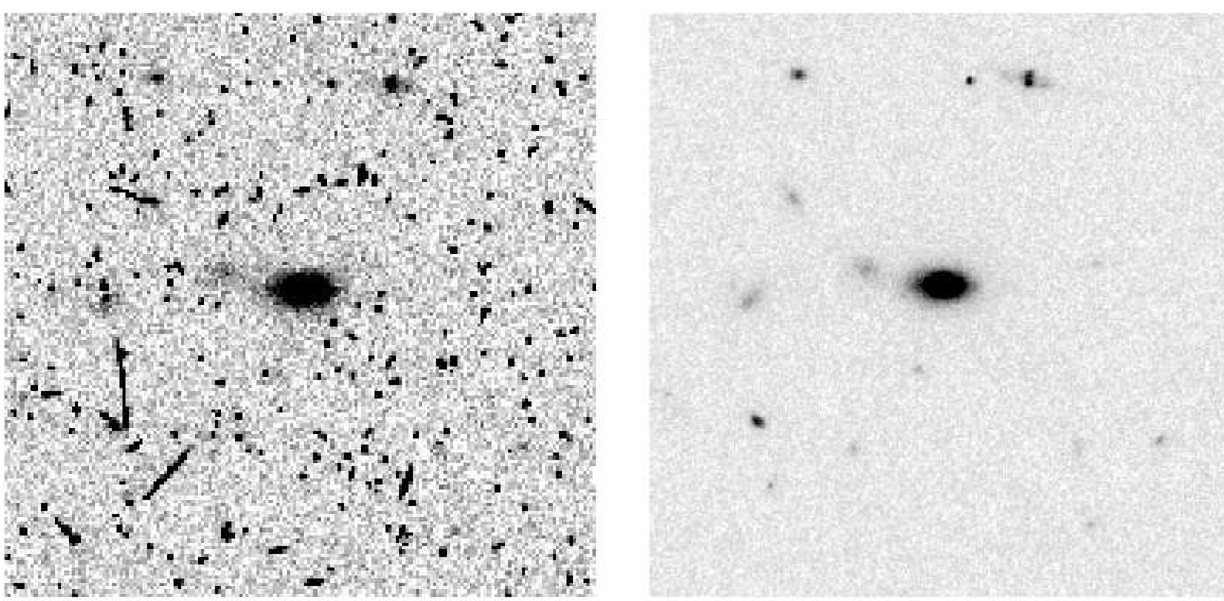
Dithering is the act of displacing the telescope between observations either on integral pixel scales (to assist in removing chip blemishes such as hot pixels) or on sub-pixel scales (to improve final image resolution). The present Handbook provides a good introduction to dithering strategies in Section 7.6; however, as our experience with processing dithered WFPC2 data is now substantially greater than when the Handbook was written, we can afford to be somewhat less conservative in our recommendations. In particular, at the time of the last writing, our experience in removing cosmic rays from singly dithered data (i.e., only one image per pointing) was quite limited. We are currently preparing IRAF scripts for beta distribution, which in conjunction with the variable pixel linear reconstruction (Drizzle) method (Fruchter and Hook, 1997), can be quite effective in processing such data. Nonetheless, users should consider the following cautionary notes before proposing to take singly dithered data:

- Processing singly dithered images can require substantially more work (and more CPU cycles) than processing data with a number of images per pointing.
- Removing cosmic rays from singly dithered WFPC2 data requires good sub-pixel sampling; therefore one should probably not consider attempting this method with WFPC2 using fewer than four images and preferably no fewer than six to eight if the exposures are longer than a few minutes and thus subject to a significant cosmic ray flux.
- It is particularly difficult to correct stellar images for cosmic rays, due to the undersampling of the WFPC2 (particularly in the WF images). Therefore, in cases where stellar photometry to better than a few percent is required, the user should take CR-split images, or be prepared to use the combined image only to find sources, and then extract the photometry from the individual images, rejecting entire stars where cosmic ray contamination has occurred.

- One must be able to determine the offset between dithered images. The jitter files, which contain guiding information, can not always be relied upon to provide accurate shifts. Therefore, one should have images that are sufficiently deep such that the offsets can be measured by observing the offsets in features in the image (typically through cross-correlation of the images). In many cases the observer would be wise to consider taking at least two images per dither position to allow a first-pass removal of cosmic rays for position determination.
- Finally, and perhaps most importantly, dithering will provide little additional spatial information unless the objects under investigation will have a signal-to-noise per pixel of at least a few at each dither position. In cases where the signal-to-noise of the image will be low, one need only dither enough to remove detector defects.

Further information on the software in development to process dithered data can be found in two papers in the *1997 HST Calibration Workshop Proceedings*: "A Package for the Reduction of Dithered Undersampled Images," by Fruchter et al., and "Dithered WFPC2 Images—A Demonstration," by M. Mutchler and A. Fruchter.

Figure 3: On the left a single 2400s F814W WF2 image taken from the HST archive. On the right, the drizzled combination of twelve such images, each taken at a different dither position.



4.0 Other HST Imaging

To be read in conjunction with Section 1.2 of the *WFPC2 Instrument Handbook,* Version 4.0

The Space Telescope Imaging Spectrograph (STIS) offers imaging capabilities in both the optical and ultraviolet that for some limited applications offers superior performance to WFPC2. The interested reader should refer to the Cycle 8 Call for Proposals for a brief overview, and the updated *STIS Instrument Handbook*, version 2, June 1998 and Section 1.2 of the *WFPC2 Instrument Handbook*, version 4, for more details.

Associated with this Cycle 8 CP is a preview of the Advanced Camera for Surveys to be available for Cycle 9 which will provide a further enhancement of HST imaging capabilities. Observers may wish to note both current and future capabilities in order to develop a long term proposal strategy.

5.0 The WFPC2 Clearinghouse

The WFPC2 Clearinghouse is a new web-based tool designed to provide users with a searchable listing of all known journal articles, STScI documentation and reports, as well as user-submitted documents which report on all aspects of the performance, calibration, and scientific use of WFPC2. The Clearinghouse can be found at the following URL:

`http://www.stsci.edu/ftp/instrument_news/WFPC2/Wfpc2_clear/wfpc2_clrhs.html`

The primary goal of the Clearinghouse is to make it easier for WFPC2 users to take advantage of the fact that there are hundreds of researchers reducing and analyzing WFPC2 data, and learning much that may be of interest to the community.

We have extensively searched through the astronomical literature and selected all articles that contain any reference or description of the calibration, reduction, and scientific analysis of WFPC2 data prior to 1998. Each article was then added to our database, with an estimate of its importance in up to 50 calibration topics. Each entry has the following format:

Author: Holtzman,Mould,Gallagher, et al.
Title: Stellar Populations in the Large Magellanic Cloud: Evidence for..
Year: 1997
Reference: AJ 113, 656
Science Keyword: IMF,LMC
Calibration Keyword(3): psf_fitting_photometry(3)
Calibration Keyword(2): bias(2)
Calibration Keyword(1): photometric_zeropoint(1)
Comment: Comparison of aperture and PSF fitting photometry,

where the category number following each keyword stands for the following:
(3)= One of the fundamental references on this topic.
(2)= Some new information on this topic.
(1)= General information on the subject.

The user can select from a large list of WFPC2 calibration related topics (see below). The results from a Clearinghouse search will list, alphabetically by author, all articles containing references to the selected topic. For journal articles, each reference is linked to that article's entry in the ADS Abstract Database, so that users can quickly determine if that particular article is relevant to their individual needs. This database will be updated periodically.

The following topics are available:

Aperture Corrections	Object Identification
Aperture Photometry	Observation Planning
Astrometry	Photometric Transformations
Bias Frames	Photometric Zeropoint
Bias Jumps	Pipeline Calibration
Calibration Observations	Polarization
CCD Characteristics	PSF Characterization
Charge Transfer Traps	PSF Fitting Photometry
Chip-to-Chip Normalization	PSF Subtraction
Completeness Corrections	Quad Filters
Cosmic Rays	Recalibration
CTE Losses	Red Leaks
Darks	Residual Images
Data Quality	Saturated Data

Deconvolution	Scattered Light
Dithering	Serial Clocks
Drizzle	Size Measurements
Field Distortion	Software
Flats	Surface Photometry
Focus	SYNPHOT
Hot Pixels	T=77 Observations
Image Anomalies	UV Throughput
Linear Ramp Filters	Vignetting
Long vs. Short Exposures	Woods Filters
Narrow Band Photometry	1997 Servicing Mission

6.0 Updates to System Efficiencies and Zeropoints

To be read in conjunction with Section 6.1 of the *WFPC2 Instrument Handbook,* Version 4.0.

Table 2 is an update to Table 6.1 of the *WFPC2 Instrument Handbook*. New calibration information has caused us to change the estimated efficiencies and throughputs of several of the narrowband and UV filters since the last publication of this table. These numbers are accurate to at least 10%—which is sufficient for planning observations, but not for the analysis of many programs. Investigators wishing to do photometry on WFPC2 images should examine the *HST Data Handbook* for an explanation of the conventions used in determining WFPC2 zeropoints and should use the zeropoints given in Table 28.1 of the Data Handbook. For the most accurate and up-to-date calibrations you may wish to examine the on-line version of the Data Handbook to make sure that no numbers of interest to you have changed since the last paper publication.

Table 2: System Efficiencies and Zeropoints

Filter	$\int QTd\lambda/\lambda$	$\bar{\lambda}$	$\delta\bar{\lambda}$	σ	QT_{max}	$d\bar{\lambda}/d\alpha$	λ_p	$\langle\lambda\rangle$	λ_{max}	$m_{e/sec}$	t_{wfsky}
F122M	0.00012	1419.7	438.2	0.1311	0.00118	24.40	1748.5	2018.0	1258	18.69	1.7E+06
F130LP	0.09178	5115.8	4776.0	0.3965	0.12977	804.10	5786.6	6107.1	6386	25.90	
F160AW	0.00025	1491.8	448.9	0.1278	0.00075	24.36	1517.3	1530.4	1406	19.50	7.7E+05
F160BW	0.00025	1491.8	448.9	0.1278	0.00075	24.36	1517.3	1530.4	1406	19.50	7.7E+05
F165LP	0.08841	5195.6	4541.2	0.3712	0.12633	715.80	5817.0	6118.8	6386	25.86	
F170W	0.00057	1749.8	545.5	0.1324	0.00178	30.67	1824.6	1872.6	1834	20.38	3.5E+05
F185W	0.00035	1952.9	335.0	0.0729	0.00188	10.37	1971.9	1983.1	1936	19.86	9.1E+06
F218W	0.00057	2191.6	387.9	0.0752	0.00275	12.38	2205.2	2212.2	2248	20.38	5.6E+06
F255W	0.00078	2585.8	393.2	0.0646	0.00452	10.78	2597.3	2603.1	2546	20.73	4.1E+06
F300W	0.00519	2942.8	735.8	0.1062	0.01838	33.17	2981.9	3002.7	2866	22.78	7.1E+04
F336W	0.00403	3342.2	381.1	0.0484	0.02872	7.84	3359.4	3369.2	3456	22.51	3.3E+04
F343N	0.00006	3432.9	27.3	0.0034	0.00691	0.04	3440.4	3445.6	3432	17.94	2.2E+06
F375N	0.00008	3737.5	27.3	0.0036	0.00774	0.04	3743.0	3746.7	3737	18.14	7.5E+05
F380W	0.00693	3964.4	673.0	0.0721	0.03406	20.61	3984.8	3995.0	3994	23.10	7.8E+03
F390N	0.00029	3888.7	45.2	0.0049	0.01880	0.10	3889.6	3890.3	3885	19.65	1.9E+05
F410M	0.00164	4090.1	146.7	0.0152	0.03619	0.95	4092.6	4093.9	4098	21.53	3.3E+04
F437N	0.00019	4370.3	25.3	0.0025	0.02681	0.03	4369.6	4369.7	4368	19.19	1.8E+05
F439W	0.00501	4299.8	473.3	0.0467	0.03436	9.40	4309.6	4314.4	4186	22.74	6.9E+03
F450W	0.01501	4519.1	956.6	0.0899	0.07955	36.52	4555.1	4572.9	5066	23.94	2.3E+03
F467M	0.00216	4668.7	166.7	0.0152	0.04825	1.07	4669.9	4670.5	4732	21.83	1.6E+04
F469N	0.00023	4694.4	24.9	0.0022	0.03267	0.02	4694.5	4694.5	4699	19.40	1.5E+05
F487N	0.00029	4865.1	25.8	0.0023	0.04239	0.03	4865.4	4865.8	4866	19.65	8.5E+04
F502N	0.00037	5012.2	26.8	0.0023	0.05226	0.03	5013.1	5013.1	5008	19.92	6.7E+04
F547M	0.01224	5476.3	483.1	0.0375	0.10577	7.69	5484.0	5487.8	5566	23.71	2.0E+03
F555W	0.02727	5397.5	1226.4	0.0965	0.10312	50.26	5447.9	5473.3	5536	24.58	9.0E+02
F569W	0.02139	5614.2	965.7	0.0730	0.10587	29.96	5644.9	5660.3	5536	24.32	8.8E+02
F588N	0.00133	5893.5	49.0	0.0035	0.12054	0.07	5893.5	5893.6	5894	21.30	1.4E+04
F606W	0.04191	5935.0	1497.3	0.1071	0.13468	68.12	6002.3	6036.1	6194	25.05	4.5E+02
F622W	0.02649	6162.8	916.5	0.0632	0.13123	24.58	6187.5	6199.8	6416	24.55	7.1E+02
F631N	0.00078	6306.4	30.8	0.0021	0.11709	0.03	6306.4	6306.4	6306	20.73	2.4E+04
F656N	0.00045	6563.7	21.4	0.0014	0.10379	0.01	6563.7	6564.0	6561	20.13	3.4E+04
F658N	0.00063	6590.1	28.5	0.0018	0.10574	0.02	6590.8	6590.9	6596	20.49	2.4E+04
F673N	0.00104	6732.1	47.2	0.0030	0.11134	0.06	6732.2	6732.3	6736	21.04	1.5E+04
F675W	0.02169	6695.9	865.6	0.0549	0.12770	20.18	6716.1	6726.2	6634	24.34	7.1E+02
F702W	0.03206	6867.8	1382.5	0.0855	0.13397	50.19	6918.8	6944.5	6514	24.76	4.8E+02
F785LP	0.00780	8617.0	1331.7	0.0656	0.04378	37.11	8654.8	8673.9	8306	23.23	1.6E+03
F791W	0.01589	7826.3	1205.0	0.0654	0.09120	33.46	7860.5	7877.7	7364	24.00	7.9E+02
F814W	0.01799	7920.9	1488.8	0.0798	0.09937	50.47	7973.0	7999.5	7266	24.13	7.0E+02
F850LP	0.00395	9072.1	985.8	0.0461	0.03491	19.32	9091.6	9101.6	8800	22.49	2.9E+03
F953N	0.00012	9544.7	52.5	0.0023	0.01651	0.05	9544.7	9544.8	9526	18.69	9.6E+04
F1042M	0.00015	10183.5	365.0	0.0152	0.00440	2.36	10188.8	10191.1	10110	18.99	6.2E+04
FQUVN-A	0.00028	3765.4	73.1	0.0082	0.01122	0.26	3766.0	3766.6	3803	19.61	4.7E+05
FQUVN-B	0.00028	3830.2	57.1	0.0063	0.01465	0.15	3830.7	3831.3	3827	19.61	1.9E+05
FQUVN-C	0.00038	3912.9	59.3	0.0064	0.01949	0.16	3914.4	3915.0	3907	19.94	1.4E+05
FQUVN-D	0.00045	3992.3	63.5	0.0068	0.02244	0.18	3992.9	3993.2	3992	20.13	1.2E+05
FQCH4N-A	0.00075	~5433	~38	0.0028	0.09356	0.04	-	-	5443	20.68	3.3E+04
FQCH4N-B	0.00082	~6193	~44	0.0028	0.11360	0.05	-	-	6205	20.78	2.3E+04
FQCH4N-C	0.00070	~7274	~51	0.0024	0.12165	0.04	-	-	7279	20.48	2.3E+04
FQCH4N-D	0.00022	~8929	~64	0.0067	0.02786	0.39	-	-	8930	19.53	5.2E+04
POLQ_par	0.06005	5570.9	4184.5	0.3190	0.09298	566.81	6076.2	6323.3	6476	25.44	
POLQ_per	0.01299	7027.7	5153.2	0.3114	0.03744	681.43	7541.1	7766.0	7839	23.78	

7.0 WFPC2 Calibration Plan

To be read in conjunction with Section 8.10 of the *WFPC2 Instrument Handbook*, Version 4.0.

Introduction

In this section we discuss the Cycle 7 and 8 calibration plans for WFPC2. It is the policy of the Institute to attempt to obtain the necessary calibration files for the vast majority of user programs. In some cases, however, users may find that they will need to take calibration images as part of their program. If you have any doubt about the suitability of the present calibrations for a program you have in mind, please feel free to contact the WFPC2 group via E-mail to `help@stsci.edu`.

The results of the calibration programs are reported to users through the *HST Data Handbook* for results of general interest, and also through frequent Instrument Science Reports available from the STScI on-line information service. HST users should rely on these, rather than the Instrument Handbook, when highly accurate numbers are required.

Cycle 7 Overview

The main goals of the Cycle 7 Calibration Plan for WFPC2 are:

- Verify that the instrument remains stable in all its characteristics.
- Aggressively address the area of its photometric accuracy.

Its centerpiece will be, as usual, the Photometric Monitoring program (7618), consisting of regular one-orbit observations of our photometric standard GRW+70d5824, executed immediately before and after decontaminations. These observations allow us to monitor very efficiently four main areas: the overall photometric throughput of the camera, the contamination of the CCD windows, especially in the UV, the PSF properties at different wavelengths, and the OTA focus. As in the past, we rely heavily on "internal" observations for some instrument maintenance and for many other types of monitoring: decontamination (7619) to clear the contaminants from the CCD windows and to limit the growth in hot pixels; darks (7619, 7620, 7621, 7712, 7713) in order to produce up-to-date, high-quality dark frames and to identify new hot pixels in a timely manner; bias, INTFLATs, and K-spots (7619, 7622, 7623) to verify the integrity of the camera's optics and electronics chain, and the pixel-to-pixel response in the visible; Earth flats (7625) to follow variations in the overall flatfield, and UV flats (7624) to monitor the pixel-to-pixel response in the UV. Most of these programs have remained largely unchanged since the previous cycle, except that internal flats place an increasing emphasis on the INTFLAT channel because of the continuing degradation of the VISFLAT channel.

Two monitoring programs are entirely new and deserve specific mention. The Supplemental Darks program (7621, 7712, 7713) aims at obtaining a large number of relatively short darks on a very frequent basis, with the main goal of helping users identify hot pixels in their observations. The program has been designed to place the least possible burden on the scheduling system; it is understood that these additional darks will have a low priority, and they will be scheduled whenever feasible. Under normal circumstances, this program will provide up to 21 additional 1000s darks per week, thus giving users a good chance of having a dark within half a day of their observations. The Astrometric Monitor program (7627) will monitor the relative placement of the four WFPC2 CCD in the focal plane, following indications that a shift of up to a pixel may have occurred since 1994. Although this is smaller than the quoted astrometric accuracy of the chip-to-chip transformations ($0.''2$), it appears worthwhile to follow closely the behavior of the camera in this area.

Special calibrations for Cycle 7 consist of only three programs. The first, Photometric Characterization (7628), continues our group's quest for the ultimate goal of 1% photometry. Observations taken in Cycles 5 and 6 allow us to understand and limit many of the photometric uncertainties in WFPC2 observations, but there is room for improvement, especially since the WFPC2 filters differ substantially from ground-based filter sets, and therefore stars with different properties must be observed to allow significant comparisons with ground-based photometry. In Cycle 6 we included a young LMC cluster, NGC 2100, and an old open cluster, M67, both with good ground-based photometry. This Cycle we plan to repeat some of the NGC 2100 observations and to add NGC 2419, a very distant globular cluster in the Milky Way, which will allow good coverage of the bright red giants, too bright and rare in nearby clusters. We will also, as usual, carry out a filter sweep on both our primary standard, GRW+70d5824, and our reference rich field in ω Centauri.

Another program, CTE Characterization (7630), aims at a thorough exploration of the various parameters that could affect the so-called "long vs. short" anomaly, that is, the observed difference in count rates between long and short exposures. Our group has been able to quantify this effect by taking advantage of archival data and of a limited number of pointed observations. However, it is clear that a complete characterization of this anomaly, comparable to what we have recently achieved for the "CTE ramp," requires an extensive set of dedicated observations in which each of the potentially critical parameters is varied in turn.

The PSF Characterization program (7629) will continue our accumulation of data for the WFPC2 PSF library, by addressing often-used filters such as F300W, F450W, F702W which were not included in previous cycles.

An additional set of Earth flats will be taken late in Cycle 7 due to the unusual length of this Cycle. Low-level temporal variations are typically discerned in the flats on time scales of about a year. These supplemental Earth flats will allow us to continue to monitor these changes, as well as make more accurate flats for use in the latter parts of Cycle 7 and early Cycle 8.

Finally, a further calibration of the Linear Ramp Filters (LRFs) will be performed. Earlier observations have demonstrated a throughput 7% lower than expectations based on laboratory filter tracings, and showed a scatter in the photometry of 10%. These observations will allow us to determine the stability of the offset and determine whether the scatter represents variability in the filter throughput or measurement errors. Additionally, exposures of the Orion Nebula at different pointings will allow a verification of the wavelength calibration of the LRFs near major nebular lines.

We now present a summary description of each calibration program, with a statement of the purpose of the program and of how it will be carried out, plus indications of the expected products. The desired and expected accuracy of each program is also explicitly stated. Table 3 summarizes the relevant data for all programs.

An electronic version of the calibration plan is available via the World Wide Web at URL:

`http://www.stsci.edu/ftp/instrument_news/WFPC2/wfpc2_bib.html`

Details on individual proposals can be found through the HST Program Information page at URL:

`http://presto.stsci.edu/public/propinfo.html`

Table 3: WFPC2 Cycle 7 Calibration Plan

ID	Proposal Title	Frequency	Estimated Time (orbits) “External”	“Internal”	Products	Accuracy	Notes
				Routine Monitoring Programs			
7618	Photometric Monitoring	1–2/4 weeks	36		SYNPHOT	1–2%	Also focus monitor
7619	Decontamination	1/4 weeks		288	CDBS	n/a	Used together with darks, internals
7620	Standard Darks	weekly		360	CDBS, WWW	1 e/hr	Also hot pixel lists on WWW
7621+	Supplemental Darks	weekly		2016		n/a	No analysis provided
7622	Internal Monitor	2/4 weeks		72	CDBS, TIR	0.8 e/pixel	New superbias (with 7619)
7623	Internal Flats	1/4 weeks		75	TIR	0.3%	Mostly INTFLATs
7624	UV Flat Field Monitor	2/cycle	4	8		2-8%	Before and after decon
7625	Earth Flats	continuous		155	CDBS	0.3%	Also LRF, Methane quads
7626	UV Throughput	2/cycle	4		SYNPHOT	3–10%	
7627	Astrometric Monitor	2/cycle	2	2	TIPS, TIR	0.″05	Also K-spots
				Special Calibration Programs			
7628	Photometric Characterization	1	10		ISR	2–5%	Also test zeropoint differences between chips, UV vignetting, astrometry
7629	PSF Characterization	1	5		WWW	10%	Covers widely used, high-throughput filters
7630	CTE Characterization	1	14		ISR	0.01 mag	Extensive coverage of preflash levels and exposure times in F555W, spot checks in F555W, F300W, hysteresis, CTE ramp
7929	CTE Monitoring	4	4		ISR	0.02 mag	Measure changes in CTE ramp
				New Requests			
8053	Supplemental Earth Flats	1		155	CDBS	0.3%	Repeat Earth Flats towards end of cycle
8054	LRF Calibration	1	10		ISR	3–5%	Complete LRF calibration, test stability
	TOTAL TIME (including all executions)		89	3131	***Assumes Cycle 7 length of 96 weeks (22 months)***		

Proposal ID 7618: WFPC2 Cycle 7: Photometric Monitor

Purpose: Regular external check of instrumental stability. Based on Cycle 6 program 6902.

Description: The standard star GRW+70d5824 is observed before and after a decontamination using three different strategies:

1. F170W in all four chips to monitor contamination in the far UV.
2. F439W, F555W, F814W on the PC to monitor focus.
3. F160BW, F218W, F255W, F300W, F336W, F439W, F555W, F675W, F814W in a different chip each month. Some filters may be cut because of lack of time.

Observations are taken after each decontamination and before every other decontamination, resulting in 36 orbits for 24 decontamination cycles.

Accuracy: Overall discrepancies between the results of this test need to be measured to better than 2% and are expected to be less than 1% rms. This has been the case in Cycles 4 through 6. The point of the test is to measure this variation. Focus measurements have an expected accuracy of 1.5 micron, and a goal of 1 micron; the uncertainty in the focus determination is dominated by external factors, such as OTA breathing.

Products: Instrument Handbook, reports at monthly TIPS meetings, WWW (sensitivity trends); updates in UV sensitivity variation used in SYNPHOT.

Proposal ID 7619: WFPC2 Cycle 7: Decontamination

Purpose: UV blocking contaminants are removed, and hot pixels cured, by warming the CCDs to +20C for six hours.

Description: The decontamination itself is implemented via the DECON mode, in which the TECs are turned off and the CCD and heatpipe heaters are turned on to warm the detectors and window surfaces. Keeping WFPC2 warm for ~6 hours has been shown in previous Cycles to be sufficient to remove the contaminants and anneal many hot pixels; continuation of 6-hour decons is anticipated for Cycle 7.

The internal observations taken before and after each decontamination consist of: 4 biases (2 at each gain setting), 4 INTFLATs (2 at each gain setting), 2 K-spots (both at gain 15, one short and one long exposure, optimized for PC and WF), and finally, 5 darks (gain 7, clocks off). To minimize time-dependent effects, each set of internals will be grouped within 2 days and performed no more than 1 day before the decon and no later that 12 hours after the decon. To protect against residual images in the darks (which results in the irretrievable loss of the critical pre-decon hot pixel status), the darks will be executed as a non-interruptible sequence at least 30 minutes after any other WFPC2 activity.

Accuracy: This proposal is mainly designed to maintain the health of the instrument. Biases, darks and other internals taken with this proposal are used in generating appropriate reference files (see Proposals 7620 and 7622).

Products: Those obtained from use of darks, biases and other internals (see Proposals 7620 and 7622).

Proposal ID 7620: WFPC2 Cycle 7: Standard Darks

Purpose: Measure dark current on individual pixels and identify hot pixels at frequent intervals.

Description: Every week, five 1800s exposures are taken with the shutter closed. The length of the exposures is chosen to fit nicely within an occultation period. The weekly frequency is required because of the high formation rate of new hot pixels (several tens per CCD per day). Five darks a week are required for cosmic ray rejection, to counterbalance losses due to residual images, and to improve the noise of individual measurements. Even with these measures, some weeks no usable darks will be available because of residual images. Normally this results only in a longer-than-usual gap in the hot pixel lists, but in a decontamination week, information on pixels that became hot and then annealed would be lost irretrievably. For this reason, pre-decon darks are to be executed NON-INT and at least 30 minutes after any WFPC2 activity (see Proposal 7619). Normal darks do not need to be protected in this fashion. The Supplemental Darks program (7621, 7712, 7713) will provide additional information on hot pixels.

Accuracy: The required accuracy for darks is about 1 e^-/hour (single-pixel rms) for the vast majority of science applications. The expected accuracy in a typical superdark is 0.05 e^-/hour for normal pixels. The need for regular dark frames is driven by systematic effects, such as dark glow (a spatially and temporally variable component of dark signal) and hot pixels, which cause errors that may exceed these limits significantly.

Products: Weekly dark frames delivered to CDBS and monthly tables of hot pixels on the Web.

Proposal ID 7621, 7712, 7713: WFPC2 Cycle 7: Supplemental Darks

Purpose: Obtain very frequent monitoring of hot pixels.

Description: This program is designed to provide up to three short (1000s) darks per day, to be used primarily for the identification of hot pixels.

Shorter darks are used so that observations can fit into almost any occultation period, making automatic scheduling feasible. Supplemental darks will be taken at low priority, and only when there is no other requirement for that specific occultation period. This program is complementary with 7620, Standard Darks, whose longer individual observations are better suited to produce high-quality pipeline darks and superdarks, and are also carried out at higher priority. Note that hot pixels are often a cause of concern for relatively short science programs, since they can mimic or mask key features of the observations, and about 400 new hot pixels per CCD are formed between executions of the Standard Darks program (7620). These observations will be made available as a service to the GO community, and there is no plan to use them in our standard analysis and products. This program has become feasible starting in Cycle 7, due to the placement of a solid state recorder on-board HST.

Accuracy: N/A

Products: None

Proposal ID 7622: WFPC2 Cycle 7: Internal Monitor

Purpose: Verification of short-term instrument stability for both gain settings.

Description: The internal observations will consist of 8 biases (4 at each gain) and 4 INTFLATs (2 at each gain). The entire set should be run once per week, except for decon weeks, on a non-interference basis. This proposal is similar to the Cycle 6 Internal Monitor (6905).

Accuracy: Approximately 120 bias frames will be used for each superbias pipeline reference file, generated once a year; accuracy is required to be better than 1.5 e^{-}/pixel, and is expected to be 0.8 e^{-}/pixel.

Products: Superbiases delivered yearly to CDBS; TIPS reports on possible buildup of contaminants on the CCD windows (worms) as well as gain ratio stability, based on INTFLATs. A Technical Instrument Report will be issued if significant changes occur.

Proposal ID 7623: WFPC2 Cycle 7: Internal Flats

Purpose: Monitor the pixel to pixel flatfield response and the VISFLAT lamp degradation as well as detect any possible changes due to contamination. This program is a combination and continuation of the Cycle 6 VISFLAT Monitor and INTFLAT Monitor proposals (6906, 6907, respectively). The VISFLAT portion has been minimized to conserve lifetime of the CAL channel lamp.

Description: This proposal contains an INTFLAT filter sweep, a VISFLAT mini-sweep, linearity tests, and monitoring images. Monitoring is carried out by taking INTFLATs with the photometric filter set after each decon. The VISFLAT mini-sweeps (before and after decon, twice during the cycle) will include the photometric filter set at gain 7, plus the linear ramp filter FR533N at both gains to test the camera linearity. The INTFLAT sweep, taken within a two-week period, includes almost all filters, some with both blades and gains (F336W, F439W, F547M, F555W, F569W, F606W, F622W, F631N, F502N, F656N, F675W, F673N, F702W, F785LP, F814W, F1042M), others with just one blade and gain (F487N, F467M, F588N, F380W, F658N, F791W, F850LP, F953N, F450W, F300W, F390N, F410M, F437N, F469N, and F160BW). The linearity test will be done at both gains and blades using F555W, and an additional set with one blade and gain with clocks on.

Accuracy: Assuming Cycle 7 results will be similar to those from previous cycles, the VISFLATs should be stable to better than 1%, both in overall level and spatial variations (after correcting for lamp degradation), and contamination effects should be < 1%. For the INTFLATs, the signal-to-noise ratio per pixel is estimated to be similar to the VISFLATs, but the spatial and wavelength variations in the illumination pattern are much larger. However, the INTFLATs will provide a baseline comparison of INTFLAT vs. VISFLAT, in the event of a complete failure of the CAL channel system. Temporal variations in the flatfields can be monitored at the 1% level. Gain ratios should be stable to better than 0.1%.

Products: TIPS report, Technical Instrument Report if any significant variations are observed.

Proposal ID 7624: WFPC2 Cycle 7: UV Flat Field Monitor

Purpose: Monitor the stability of UV flat field.

Description: UV flat fields will be obtained with the CAL channel's ultraviolet lamp (UVFLAT) using the UV filters F122M, F170W, F160BW, F185W, and F336W. The UV flats will be used to monitor UV flat field stability and the stability of the Woods filter (F160BW) by using F170W as the control. The F336W ratio of VISFLAT (Cycle 6 proposal 6906) to UVFLAT will provide a diagnostic of the UV flat field degradation and tie the UVFLAT and VISFLAT flat field patterns together. Two supplemental dark frames must be obtained immediately after each use of the lamp, in order to check for possible after-images.

Accuracy: About 2-8% pixel-to-pixel expected (depending on filter).

Products: New UV flat fields if changes are detected.

Proposal ID 7625: WFPC2 Cycle 7: Earth Flats

Purpose: Monitor flat field stability.

Description: As in Cycle 6 program 6909, sets of 200 Earth-streak flats are taken to construct high quality narrow-band flat fields with the filters F160BW, F375N, F502N, F656N and F953N. Of these 200 perhaps 50 will be at a suitable exposure level for destreaking. The resulting Earth super-flats map the OTA illumination pattern and will be combined with SLTV data (and calibration channel data in case of variation) for the WFPC2 filter set to generate a set of superflats capable of removing both the OTA illumination and pixel-to-pixel variations in the flat fields. The general plan of Cycles 5 and 6 is repeated.

Accuracy: The single-pixel signal-to-noise ratio expected in the flat field is 0.3%.

Products: New flat fields to CDBS if changes detected.

Proposal ID 7626: WFPC2 Cycle 7: UV Throughput

Purpose: Verify throughput for all UV filters. Loosely based on the Cycle 5 and 6 UV throughput proposal (6186, 6936).

Description: GRW+70d5824 will be observed shortly before and after a DECON through all the UV filters in PC and WF3. Observations should be taken roughly mid-way through the cycle.

Accuracy: The UV throughput will be measured to better than 3%.

Products: TIPS, SYNPHOT update if necessary, Technical Report to document any changes if necessary.

Proposal ID 7627: WFPC2 Cycle 7: Astrometric Monitor

Purpose: Verify relative positions of WFPC2 chips with respect to one another. Repeats parts of Cycle 6 proposal 6942 twice during Cycle 7.

Description: The rich field in ω Cen used for the Astrometry Verification (6942) is observed with large shifts (35″) in F555W only, at two different times during Cycle 7. This will indicate whether there are shifts in the relative positions of the chips or changes in the astrometric solution at the sub-pixel level. Kelsall spot images will be taken in conjunction with each execution. The K-spots data and some external data indicate that shifts of up to 1 pixel may have occurred since mid-1994.

Accuracy: At least 0.″1 in the relative shifts, with a goal of 0.″02–0.″05.

Products: TIPS, Technical Instrument Report; update of chip positions in PDB and of geometric solution in STSDAS task **metric** if any changes are found.

Proposal ID 7628: WFPC2 Cycle 7: Photometric Characterization

Purpose: (1) Determine whether any changes in the zeropoint, or in the spatial dependence of the zeropoint or contamination, have occurred; (2) include another globular cluster (NGC 2419) in order to extend the parameter space for determinations of photometric transformation. Combines and continues Cycle 6 proposals 6934, 6935.

Description: Observations of the primary photometric standard GRW+70d5824 will be compared against baseline observations. The cluster fields in ω Cen and NGC 2100 will be compared to previously obtained data in order to test for spatial variations in the throughput. Most broad-band and intermediate-width filters, including the far UV set for NGC 2100 (very young, many blue stars). A contamination test using UV filters will also be performed for NGC 2100. New observations of the Galactic globular cluster NGC 2419 will be compared with good ground-based photometry; this cluster is very distant (100 kpc) and will provide a large color spread on giant branch and HB.

Accuracy: Photometric stability expected to be better than 2%. Photometric transformations to be defined to 2–5%, depending on filter; most of the error derives from limited knowledge of the transformations between ground-based and WFPC2 photometric systems.

Products: ISR; SYNPHOT updates if necessary.

Proposal ID 7629: WFPC2 Cycle 7: PSF Characterization

Purpose: Provide a subsampled PSF over the full field to allow PSF fitting photometry, test PSF subtraction as well as dithering techniques. Based on Cycle 6 program 6938.

Description: Measure PSF over full field in often-used, high-throughput filters in order to update the Tim and TinyTim models and to allow accurate empirical PSFs to be derived for PSF fitting photometry. Compared to Cycles 5 and 6, we will repeat F814W to provide a continuing baseline, and will replace the other filters with F300W, F450W, F606W and F702W, which are often used because of their high throughput but are not as well characterized as the photometric set (F336W, F439W, F555W, F675W) used in previous Cycles. These observations will also be useful in order to test PSF subtraction and dithering techniques at various locations on the CCD chips. With one orbit per photometric filter, a spatial scan is performed over a 4 x 4 grid on the CCD. The step size is 0.025 arcseconds; this gives a critically sampled PSF over most of the visible range. This program uses the same specially chosen field in ω Cen as the Cycle 5 proposal 6193. The proposal also allows a check for sub-pixel phase effects on the integrated photometry.

Accuracy: Provides measurement of pixel phase effect on photometry (sub-pixel QE variations exist). The chosen field will have tens of well exposed stars in each chip. Each star will be measured 16 times per filter at different pixel phase. The proposal therefore provides, in principle, a high signal-to-noise, critically sampled PSF. This will improve the quality of PSF fitting photometry for the filters used. The result will be largely limited by breathing variations in focus. It is difficult to predict the PSF accuracy that will result. If breathing is less than 5 microns peak-to-peak, the resulting PSFs should be good to about 10% in each pixel. In addition, the test gives a direct measurement of sub-pixel phase effects on photometry, which should be measured to better than 1%.

Products: PSF library (WWW).

Proposal ID 7630: WFPC2 Cycle 7: CTE Calibration

Purpose: Conduct a thorough examination of the variation in photometric zeropoint as a function of exposure length, background (via preflash), and position in the chip. Include spot checks for the dependence of zeropoint variations on filter, order of exposures, and camera shifts (CTE ramp).

Description: A well-studied field in the globular cluster NGC 2419 will be observed through F814W with a combination of exposure times (10, 40, 100, 300, 1000s) and preflash levels (0, 5, 10, 100, and 1000 e^-). Completes Cycle 6 proposal 6937, which was shortened substantially because of SM constraints. Will also include several observations in reverse order (to test for hysteresis), in F555W and F300W (filter dependence), and after a pointing shift (to test for x, y dependence), as well as a series of equal-length exposures to test the effect of noiseless preflash. This proposal should improve substantially our understanding of CTE and of the long vs. short anomaly.

Accuracy: The reported short vs. long effect is ~0.05 mag. We want to determine it to better than 0.02 mag, with a goal of 0.01 mag.

Products: ISR, paper; if appropriate, a special task to correct the CTE effect will be generated.

Proposal ID 7929: WFPC2 Cycle 7: CTE Monitor

Purpose: Monitor variations in CTE ramp for bright and faint targets.

Description: Analysis of Cycle 6 CTE data shows that the CTE ramp depends strongly on stellar magnitude and background, and that its amplitude varies in time for faint stars. However, most measurements have been taken so far under slightly different conditions from one another. This program will take four one-orbit measurements of the CTE at four month intervals, under the same conditions as the best data taken so far. It will provide an accurate and efficient tracer of changes in the CTE ramp, and show to what extent WFPC2 remains a photometric instrument for faint objects. Observations of the standard field in NGC 5139 will be taken at the same roll angle, but centered in each of the WF chips in turn, thus reversing the x and y positions of each star. No preflash test is included.

Accuracy: The measurements will enable tracking of the CTE ramp with an accuracy requirement of 0.02 mag, and a goal of 0.01 mag.

Products: ISR.

Proposal ID 8053: WFPC2 Cycle 7: Supplemental Earth Flats

Purpose: Repeat the sequence of Earth Flats late in Cycle 7 to verify stability of flat field.

Description: As in previous cycles and earlier in Cycle 7, sets of 200 Earth-streak flats are taken to construct high quality narrow-band flat fields with the filters F160BW, F375N, F502N, F656N and F953N. Of these 200 perhaps 50 will be at a suitable exposure level for destreaking. The resulting Earth superflats map the OTA illumination pattern and will be combined with SLTV data (and calibration channel data in case of variation) for the WFPC2 filter set to generate a set of superflats capable of removing both the OTA illumination and pixel-to-pixel variations in the flat fields. A repeat is requested because of the length of Cycle 7 and the fact that low-level temporal variations are typically discerned on time scales of about a year.

Accuracy: Large-scale flat field variations can be tracked to about 0.3%.

Products: New flat fields will be generated and delivered.

Proposal ID 8054: WFPC2 Cycle 7: LRF Calibration

Purpose: Complete the analysis of LRF properties: throughput and wavelength scale.

Description: The primary spectrophotometric standard GRW+70d5824 will be observed at several locations on the three most used Linear Ramp Filters to verify its throughput as a function of wavelength. In addition, exposures of the Orion Nebula at two different pointings will be used to verify the wavelength calibration of the LRF at the wavelengths of major nebular lines. Previous executions of the LRF calibration have demonstrated a throughput consistent with the expectations based on laboratory filter tracings, with a scatter of 8% rms. The series of observations of GRW+70d5824 will: 1) measure the temporal stability of the difference between measured and predicted throughput; 2) demonstrate whether the scatter is due to measurement errors or to intrinsic variations in the filter; 3) complete the wavelength coverage (some of the observations from previous programs were lost); and 4) and provide more closely spaced points in the most often used ramp filter. The observations of the Orion Nebula, at two carefully optimized pointings, will provide a direct test of the wavelength calibration and vignetting of the LRF at the wavelengths of Hα, Hβ, [OIII], [NII] and [SII].

Accuracy: Measure throughput to 5%, wavelength position to about 5–10 pixels.

Products: ISR, new SYNPHOT tables.

Cycle 8 Overview

In the previous section we described the Cycle 7 calibration plan. We expect the Cycle 8 calibration plan to largely mirror the Cycle 7 plan with two exceptions: we do not presently expect to continue either the PSF characterization program (7629) or the CTE characterization program (7630). We expect to obtain the necessary data for these programs in Cycle 7. We have recently added a Linear Ramp Filter (LRF) Calibration program to the Cycle 7 plan due to a recent discovery that errors in the LRF throughput may be as high as 8% rather than the 3% previously estimated. We do not expect that this program will be continued in Cycle 8, however. Similarly, we have no plans at present to include any further polarization calibration in Cycles 7 or 8; however, analysis of previous polarization calibration data is ongoing, and should any anomalies be found, we will adjust the calibration plans accordingly.

8.0 References

- Casertano, S., et al., editors, *The 1997 HST Calibration Workshop Proceedings*, STScI, 1998.

  `http://www.stsci.edu/stsci/meetings/cal97/proceedings.html`

- Fruchter, A. S., Hook, R. N., 1997, “A novel image reconstruction method applied to deep Hubble Space Telescope images," in *Applications of Digital Image Processing XX*, Proc. SPIE, Vol. 3164, A. Tescher, editor, p.120.
- Holtzman, J., et al., (1995a), “The Performance and Calibration of WFPC2 on the Hubble Space Telescope,” *PASP*, 107, 156.
- Holtzman, J., et al., (1995b), “The Photometric Performance and Calibration of WFPC,” *PASP*, 107, 1065.

- Voit, M., ed., *HST Data Handbook*, (Version 3.0, October 1997).

  `http://www.stsci.edu/documents/data-handbook.html`

- Whitmore, B. 1998, "Time Dependence of the Charge Transfer Efficiency on the WFPC2."

  `http://www.stsci.edu/ftp/instrument_news/WFPC2/Wfpc2_isr/cte_vs_time_post.ps`

- Whitmore, B., Heyer, I. 1997, ISR 97-08 "New Results on Charge Transfer Efficiency and Constraints on Flat-Field Accuracy."

  `http://www.stsci.edu/ftp/instrument_news/WFPC2/Wfpc2_isr/wfpc2_isr9708.html`